MASTER OF SCIENCE
IN
OPERATIONS RESEARCH

OPTIMALLY SCHEDULING EA-6B DEPOT MAINTENANCE AND AIRCRAFT MODIFICATION KIT PROCUREMENT

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The Department of the Navy maintains a fleet of 124 EA-6B aircraft, the only tactical electronic warfare aircraft in the Department of Defense inventory. Already 30 years old and not to be retired until 2015, the EA-6B requires depot maintenance services to remain combat ready. EA-6B aircraft undergo standard depot level maintenance (SDLM) about every eight years. In addition to SDLM, depots must complete 72 wing center section replacement services and over 175 major aircraft modification services by 2010. Navy regulations govern when each EA-6B is eligible for each service; these rules are flexible enough to allow more induction schedules than can be evaluated manually in a reasonable amount of time. Because each service keeps an aircraft at the depot for six to 14 months and performing multiple services together requires less time than performing services independently, services should be combined whenever possible.

This thesis introduces DMAAP (Depot Maintenance and Acquisition Planner); a prototypic optimization based decision support tool to assist in scheduling EA-6B depot level maintenance services and major aircraft modification kit acquisition. DMAAP produces a Master Plan (induction schedule) providing a monthly schedule for the first six years, a yearly schedule out to 2013 and yearly major aircraft modification kit acquisition levels out to 2010. We compare DMAAP Master Plans obtained using alternate depot induction policies to demonstrate DMAAP's ability and show how yearly depot workloads and yearly operational aircraft vary under alternate policies.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Integer Linear Programming, Aircraft Depot Maintenance, Optimization, EA-6B, SDLM (Standard Depot Level Maintenance)

OPTIMIZATION OF UNITED STATES MARINE CORPS OFFICER CAREER PATH SELECTION

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The Marine Corps Manpower System is responsible for managing the Marine officer inventory. The system's primary objective is to maximize the Marine Corps' operational readiness through the assignment of officers to billets. While striving to fulfill billet requirements, the manpower system simultaneously develops the professional skills, or core competencies, that each officer must possess to be assigned to billets requiring more authority and responsibility. Therefore, officer careers (or career paths) must reflect a balance between fulfilling billet requirements and developing core competencies. Currently, Marine

Corps manpower planners lack rigorous methods to assist them in understanding the effects of various personnel policy decisions on the average officer career path or the system's ability to meet future billet requirements.

To assist these planners, this thesis presents an integer program, the Officer Career Path Selection (OCPS) Model. The goal of OCPS is to assign officers to acceptable career paths in order to best meet billet requirements while satisfying, among others, core competency and tour length constraints. This thesis uses data from the Infantry Marine Occupational Specialty (MOS) to illustrate that outputs from OCPS provide useful information regarding the number of annual Infantry officer accessions and the effects of potential manpower policy decisions.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Manpower Planning, Optimization, Set-Covering

AN EVALUATION OF SEA-BASED SUSTAINMENT OF FORCES
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The Marine Corps has formed a vision of how to conduct future amphibious warfare through its development of Operational Maneuver From the Sea (OMFTS), Ship-to-Objective Maneuver (STOM), and Sea-Based Logistics (SBL) concepts. These concepts have forces deploying directly from ship to objectives ashore with a reduction or elimination of logistics infrastructure ashore. Combat forces operating ashore will be sustained directly from a sea-base with support from ship-to-shore transporters. By sea basing logistics functions, there will be a much greater demand upon these transporters. This thesis models the sea-based sustainment of Marine Expeditionary Brigade (MEB) forces deployed from amphibious warfare ships. A scenario for analysis is developed with force packages of personnel and equipment located at certain locations ashore during different days of an operation. Sustainment requirements and available transporter capacity are then determined and compared for twenty-seven cases comprising different ship-to-shore distances, different levels of aircraft attrition due to enemy interdiction, and different footprints of mobile logistics forces deployed ashore. This comparison provides insight into the ability of SBL to sustain forces ashore conducting operations in accordance with OMFTS and STOM concepts.

DoD KEY TECHNOLOGY AREA: Other (Logistics)

KEYWORDS: Operational Maneuver From The Sea (OMFTS), Ship-to-Objective Maneuver (STOM), Sea-Based Logistics (SBL)

IMPROVING NOMINAL RELIABILITY CONFIDENCE BOUNDS USING COVERAGE PROBABILITIES GENERATED THROUGH MONTE CARLO SIMULATION AND ILLUSTRATED BY MONTE CARLO SIMULATION
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Estimating the failure time of a product with a high degree of confidence is a difficult endeavor. Clearly, if the product is inexpensive and fails quickly, extensive tests can be run to make prediction more accurate. When the item under scrutiny is expensive, not prone to failure, or both, calculating accurate estimates and confidence bounds becomes more difficult. Furthermore, many methods currently in use are prone to error, sometimes making a critical part appear more reliable than it actually is. Much of our military uses end-

items that fall into this category. The lives of our soldiers, sailors, airmen, and Marines often depend on accurate reliability estimates for the equipment and weapons they work on every day.

This thesis first introduces reliability and the common techniques for measuring it. Secondly, it shows that these estimates are often biased. Next, this bias is quantified using Monte Carlo simulation and corrected through simple tables and equations. The tables and equations can be used to map nominal confidence bounds to actual confidence bounds. Lastly, these results are applied to a Marine Corps program and a test run at a major automotive brake system manufacturer. These examples will illustrate the impact of uncorrected bias and what can be done to correct it.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Reliability, MLE, Rank Regression, Confidence Bounds, B1, Coverage Probabilities, Monte Carlo Simulation, Weibull

OPTIMIZATION OF PROCUREMENT SCHEDULING FOR MAJOR DEFENSE ACQUISITION PROGRAMS

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As the Defense Acquisition Executive (DAE), the Under Secretary of Defense for Acquisitions, Technology and Logistics has full responsibility for supervising the performance of the DoD Acquisition System. A challenge to the DAE is in determining the most efficient allocation of funding in procuring of over eighty Major Defense Acquisition Programs. This thesis develops six different cost functions based on the Unit Theory learning curve model for estimating the cost of each of these MDAP systems. The most suitable of these adds an annual overhead component to the cost modeled by the learning effect. This function is implemented in an integer-linear optimization model, the Procurement Scheduling Optimization Model (PSOM). PSOM allows the planner to specify: an annual budget limit; demand quantities for each system for all years in the planning horizon; minimum and maximum annual production rates; earliest and latest full rate production (FRP) start periods; and low rate initial production (LRIP) costs and quantities. PSOM determines the minimum cost procurement schedule given these constraints, finding the optimal quantity of each system to be procured each year of the planning horizon. This thesis models the cost of seventeen of the MDAP systems and optimally schedules them over an eighteen year planning horizon. PSOM can easily be expanded to include all eighty-plus MDAP systems. PSOM is a tool available to the acquisition planners and decisionmakers to assist in optimally allocating procurement funding.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Acquisition, Procurement, Cost Estimation, Learning Curve, MDAP, Optimization, Linear Program, Integer-Linear Program

PLANNING FLIGHT TRAINING FOR THE TRANSITION TO THE V-22 OSPREY

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The Department of Defense is fielding the V-22 Osprey tilt-rotor aircraft in the Marine Corps and Air Force. Marine Medium Tilt-Rotor Training Squadron 204 (VMMT-204) in Jacksonville, North Carolina, is the sole Fleet Replacement Squadron (FRS) for initial V-22 training, and planners must develop pilot training schedules that support service goals without exceeding VMMT-204 resources. Currently, planners

manually create FRS training schedules with monthly fidelity, guided by past analysis and personal experience. However, manual methods are cumbersome and provide few measures of resource utilization. Marine planners need a decision support tool to automate V-22 FRS scheduling, given transition guidance. This thesis introduces an optimization model that takes as input Marine Corps operational requirements, Air Force and Marine annual training goals, FRS training syllabus requirements and resources available, and a prioritization scheme to resolve conflicts between competing goals. The output is a schedule of training classes identified by unit, FRS syllabus and follow-on training, and class convening date (with half-month fidelity) over a ten-year planning horizon. The model uses Microsoft Excel to input data and automate output reports for training goals, resource utilization, and training possibilities with unscheduled resources. A ten-year training plan can be completed in about 10 minutes.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel, and Training, Air Vehicles, Modeling and Simulation, Computing and Software, Conventional Weapons

KEYWORDS: Decision Support, Manpower Planning, Linear Programming, V-22 Osprey, Flight Training

DETERMINISTIC AND STOCHASTIC MODELS OF BIOLOGICAL ATTACKS ON SEAPORTS OF DEBARKATION DURING A MAJOR THEATER WAR

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Alexander [1999] develops deterministic and stochastic optimization models to study how a biological weapons attack upon a Seaport of Debarkation (SPOD) during a Major Theater War (MTW) can disrupt the force build-up required to support that war. Force disruption is measured by lateness of cargo and non-deliveries. The current research improves the realism of those models: Ships may now be re-routed away from an SPOD that has just been attacked (to an alternate SPOD with spare cargo-handling capacity), and cargo cannot be unloaded until decontamination is complete. The improved models are tested using unclassified data that simulates requirements for an MTW in the Persian Gulf. Results indicate that re-routing of ships is beneficial if the re-routing delay, measured by the time to travel to the alternate SPOD, is less than the time required to decontaminate the attacked SPOD. Uncertainty in the timing of the biological attack is handled by the stochastic model, which minimizes the sum of expected disruption over several possible attack scenarios. Results show that limited intelligence about a potential attack can mitigate the disruption that attack might cause.

DoD KEY TECHNOLOGY AREAS: Chemical and Biological Defense, Modeling and Simulation

KEYWORDS: Optimization, Stochastic Optimization, Biological Warfare

THORN: A STUDY IN DESIGNING A USABLE INTERFACE FOR A GEO-REFERENCED DISCRETE EVENT SIMULATION

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This thesis evaluates the usability of THORN: a system for displaying a discrete event simulation model in a geographic information system. THORN was developed to enhance the planning phase of Operational Maneuver from the Sea. The goals of this study were to test the system against usability criteria and

provide a benchmark for future testing. The purpose of this analysis was to (1) create a system for viewing discrete event simulations fused with geo-referenced spatial information, (2) determine the system's usability, (3) identify problem areas in the graphical user interface, and (4) provide a proof of concept for incorporating usability in the design of military planning tools. The study's scenario is based on the principles outlined in the white paper Operational Maneuver from the Sea. The study tested whether THORN met the usability objectives of (a) 90% successful tasks completion, (b) ease-of-use ratings of "somewhat easy" or better, and (c) satisfaction ratings of "somewhat satisfied" or better. THORN met all of these usability objectives.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Computing and Software, Modeling and Simulation

KEYWORDS: Operational Maneuver From the Sea, GIS, Simulation, Software Components

AN EVENT-STEP SIMULATION FOR EVALUATING DD21 SYSTEM EFFECTIVENESS
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During design of the U.S. Navy's 21st Century Destroyer (DD21), Lockheed Martin is considering various measures of readiness to aid in evaluating how the ship's maintainability affects overall effectiveness. Availability, dependability and capability are all worthwhile measures of effectiveness, but do not get at the true question: "What is the probability that DD21 can "complete" some randomly arriving mission?" This thesis develops an object-oriented discrete-event Monte Carlo simulation to answer this question for DD21. Using design data from Lockheed Martin, this thesis analyzes the system effectiveness of DD21, within its Land Attack mission. Additionally, this thesis examines how drastically DD21's system effectiveness will be reduced without immediate knowledge of component failures.

DoD KEY TECHNOLOGY AREAS: Surface Vehicles, Manufacturing Science and Technology, Modeling and Simulation

KEYWORDS: Modeling, Simulation, Navy, Ship, Failure, Maintenance, Availability, System Effectiveness

A SIMULATION OF THE JOINT TACTICAL RADIO SYSTEM BANDWIDTH REQUIREMENTS TO SUPPORT MARINE CORPS SHIP-TO-OBJECTIVE MANEUVER IN 2015
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The United States Marine Corps is exploring the concepts of Operational Maneuver From the Sea (OMFTS) and Ship-To-Objective Maneuver (STOM) as methods for employment of maritime forces in the future. At the same time, the Department of Defense (DoD) is pursuing the acquisition of the Joint Tactical Radio System (JTRS), a multi-band, multi-channel, multi-mode family of radios, designed to form self-organizing, self-healing communications networks. The JTRS will have to support Marine forces in combat at long distances from the forces' support and higher headquarters units. This extended range will require the use of relay radios in order to maintain connectivity between the attacking force and its support.

This thesis explores the relay station bandwidth requirements to support Marine forces. The question is analyzed through the use of a discrete-event simulation written in Java, which models the behavior of a

JTRS network in a STOM scenario. Quality of service of the communication network is measured by timely delivery of messages.

The results of the simulation indicate that the JTRS network performance is insensitive to relay station bandwidth. Rather, the subordinate headquarters involved in the scenario were the most overloaded nodes in the network.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Command, Control and Communications

KEYWORDS: C4I, Simulation, Java, Object-Oriented, JTRS, STOM, OMFTS

AGENT-BASED SIMULATION OF MILITARY OPERATIONS OTHER THAN WAR SMALL UNIT COMBAT

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A significant challenge to the Armed Forces today is the development of tactics, techniques, procedures, and equipment that will enable success in the small-scale combats that characterize Military Operations Other Than War (MOOTW). This thesis develops an agent-based simulation methodology for modeling MOOTW combat scenarios. The methodology combines agent-based modeling with discrete event simulation in a software package called AgentKit. AgentKit is used to model a riot control problem for an experiment that pits two kinds of tactics against two different kinds of crowds. This simulation yields insights into the scenario modeled and demonstrates the usefulness of agent-based simulation for the exploration of tactical concepts in a MOOTW context.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Agents, Modeling and Simulation, Object Oriented Programming, Java, Military Operations Other Than War, Riot Control, Peacekeeping